A high order solver for the unbounded Poisson equation with specific application to the equations of fluid kinematics

Hejlesen, Mads Mølholm; Rasmussen, Johannes Tophøj; Walther, Jens Honore; Chatelain, P.

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A high order solver for the unbounded Poisson equation with specific application to the equations of fluid kinematics M. M. HEJLESEN, J. T. RASMUSSEN, Department of Mechanical Engineering, Technical University of Denmark, Building 403, DK-2800 Kgs. Lyngby, Denmark, P. CHATELAIN, Institute of Mechanics, Materials and Civil Engineering, Universite catholique de Louvain, B-1348, Belgium, J. H. WALTHER[1], Department of Mechanical Engineering, Technical University of Denmark, Building 403, DK-2800 Kgs. Lyngby, Denmark — This work improves upon Hockney and Eastwood's Fourier-based algorithm for the unbounded Poisson equation to formally achieve an arbitrary high order of convergence. The high order convergence is achieved by constructing regularized Green's functions through a filtering procedure. High order filters and regularized kernels are obtained by canceling the corresponding moments, a task which we show can be performed through a recursive application of extrapolation. We assess the methodology on the kinematic relations between the velocity and vorticity fields. In fluid mechanics the velocity is determined from the curl of the stream function which in turn is related to vorticity through the Poisson equation. The curl operator can be computed analytically, as a multi-component convolution kernel or, alternatively, computed directly in Fourier space through a spectral differentiation of the convolution product. The latter solution allows to reduce the computational cost and memory footprint of the algorithm while conserving its convergence order.

[1]Also at: Computational Science and Engineering Laboratory, ETH Zurich, Universitatsstrasse 6, CH-8092, Zurich, Switzerland

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Department of Mechanical Engineering, Technical University of Denmark, Buildin

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